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Construct validity of the international standards to document remaining autonomic function after spinal cord injury (ISAFSCI) (1st edition)

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STUDY DESIGN: Observational study.
OBJECTIVES: To assess the construct validity of the International Standards to Document Remaining Autonomic Function after Spinal Cord Injury (ISAFSCI) (2012 1st Edition).
SETTING: Two Canadian spinal cord injury (SCI) centers.
METHODS: Data were collected between 2011–2014. Assessments included the ISAFSCI, standardized measures of autonomic function and a clinical examination. Construct validity of ISAFSCI was assessed by testing a priori hypotheses on expected ISAFSCI responses to standard measures (convergent hypotheses) and clinical variables (clinical hypotheses).
RESULTS: Forty-nine participants with an average age of 45 ± 12 years were included, of which 42 (85.7%) were males, 37 (77.6%) had a neurological level of injury at or above T6, and 23 (46.9%) were assessed as having motor and sensory complete SCI. For the six General Autonomic Function component hypotheses, two hypotheses (1 clinical, 1 convergent) related to autonomic control of blood pressure and one clinical hypothesis for temperature regulation were statistically significant. In terms of the Lower Urinary Tract, Bowel and Sexual Function component of the ISAFSCI, all the hypotheses (5 convergent, 3 clinical) were statistically significant except for the hypotheses on female sexual items (2 convergent, 2 clinical), likely due to small sample size.
CONCLUSION: The construct validity of ISAFSCI (2012 1st Edition) for the General Autonomic Function component was considered to be weak while it was much stronger for the Lower Urinary Tract, Bowel and Sexual Function component based on a priori hypotheses. These results can inform future psychometric studies of the ISAFSCI (2021 2nd Edition).

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INTRODUCTION

Traumatic spinal cord injury (SCI) may result in profound impairments of motor, sensory and autonomic function, which can result in significant disability [1, 2]. To help predict the severity of SCI, the International Standards for the Neurologic Classification of Spinal Cord Injury (ISNCSCI) is widely used as a reliable and valid measure for documenting remaining motor and sensory function following SCI [3, 4]. While the ISNCSCI does provide an assessment of motor and sensory function after SCI, it does not assess SCI-related impairments of the autonomic nervous system (e.g. cardiovascular, temperature regulation, bowel, bladder, and sexual function). Abnormalities of autonomic function significantly affect the quality of life for individuals living with SCI, and detection is important as treatments are available to assist in mitigating these abnormalities [5, 6].

To enhance the detection of autonomic impairments after traumatic SCI, the autonomic standards were developed by a joint committee of the American Spinal Injury Association (ASIA) and International Spinal Cord Society (ISCoS) in 2009 [7]. The International Standards to Document Remaining Autonomic Function after Spinal Cord Injury first edition (ISAFSCIv1) was published in 2012 [8], and is used among clinicians and researchers worldwide [9–12]. A Spanish version of the ISAFSCIv1 was used in a study and reported to be a useful tool in clinical practice [13]. The inter-rater reliability of ISAFSCIv1, evaluated by Davidson et al. was reported to be moderate to strong [14]. Feedback received from clinicians, researchers and other relevant literature prompted a further revision to ISAFSCI and the second edition of ISAFSCI (ISAFSCIv2) was recently published in 2021 [15]. Currently, both versions of the ISAFSCI assessment form are available for download on the ASIA website [16].

A number of improvements were made in the ISAFSCIv2. In addition to changes in language and clarifications, definitions of abnormal conditions for the General Autonomic Function component and anticipated function based on ISNCSCI for the Lower Urinary Tract, Bowel and Sexual Function component were

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added to the assessment form. The scoring for the General Autonomic Function component changed from a nominal ('present' or 'absent') to an ordinal scale (normal = 2, altered = 1 and absent = 0 when applicable) to be consistent with the scoring method for the Lower Urinary Tract, Bowel and Sexual Function component [15] (see Supplementary Fig. 1 for the two versions of ISAFSCI assessment forms). To our knowledge, there have not been any previous studies that have examined the validity of either version 1 or 2 of the ISAFSCI.

Validity refers to whether a measure assesses what it intends to measure. Instead of being a property of a measure, validity is the extent to which the meaning of the results from a measure can be warranted for a particular purpose [17]. Construct validity assesses the theoretical relationship of the responses to items or scores for the measure to other measures assessing similar constructs referred to as convergent validity [18]. In addition, construct validity can be assessed by testing a priori hypotheses on how the measure will perform based on clinical variables such as injury level and severity.

The objective of this study was to assess the construct validity of the ISAFSCIv1. This was done by testing a priori hypotheses on the expected correlation between ISAFSCI items for the General Autonomic Function component and Lower Urinary Tract, Bowel and Sexual Function component and similar items and/or domains in other standard measures. In addition, clinical hypotheses on ISAFSCI responses to items based on clinical assessments such as neurological level and injury severity were tested. Validation studies using ISAFSCIv1 can inform future studies of ISAFSCIv2 given the similarities between the two versions (e.g., the Lower Urinary Tract, Bowel and Sexual Function component is the same in both versions of ISAFSCI).

METHODS

Study design

We conducted an observational study between June 2011 and April 2014 at two Canadian SCI centers: Vancouver, British Columbia and Kingston, Ontario. The inclusion criteria for participants consisted of a diagnosis of traumatic SCI, at least one-year post-injury, age ≥18, and ability to read English and provide informed consent. Participants were required to have no changes in neurological function within the last three months and no change in their medications for the entire study period. Research Ethics Board (REB) approval from the hospital and university was obtained for both sites.

Study procedures

Study participants attended two research visits. During the first visit, participant eligibility was confirmed, informed consent was obtained, demographic information was collected, blood pressure and heart rate were measured, the ISNCSCI was performed, and the ISAFSCIv1 was completed by an assessor. At the second visit, a different assessor obtained measurements of blood pressure and heart rate, and administered the ISAFSCIv1. The ISNCSCI examination was completed for each participant from which neurological level, injury severity (AIS A to D), motor, and sensory scores were obtained. Although motor and sensory scores were obtained clinically, only ISNCSCI pinprick scores were used for analysis in this study. Specifically, an average of ISNCSCI pinprick scores at neurological levels T10, T11, T12, and L1 (ISNCSCI composite pinprick score) was used. Standardized measures of autonomic functions described below were administered. Full details of the study design and procedures have been described elsewhere [14].

ISAFSCIv1 assessment. The ISAFSCIv1 assessment consists of: (1) General Autonomic Function component and (2) Lower Urinary Tract, Bowel and Sexual Function component. The General Autonomic Function component has five sections including autonomic control of the heart (4 items), autonomic control of blood pressure (4 items), autonomic control of sweating (4 items), temperature regulations (3 items), and autonomic and somatic control of broncho-pulmonary system (4 items). Items in this component are evaluated with a nominal response of 'present' or 'absent' using a check mark. The Lower Urinary Tract, Bowel and Sexual Function component consists of three sections including lower urinary tract (2 items), bowel (3 items) and sexual function (5 items). Items are scored zero, one or two and evaluated using an ordinal scale where a score of two represents a normal function, one represents a reduced or altered function and zero means complete loss of control. Items that are unable to be assessed due to pre-existing or concomitant problems are coded as 'NT' (not testable) [8]. In order to standardize the study protocol, standard questions were developed by the project team to assist with performing the ISAFSCI assessment (see Appendix 1) [14].

Standard measures for comparison. Measures to assess the expected correlations were the Autonomic Symptom Profile (ASP) [19], the Quality of Life of Spinal Cord Injury Patients (Qualiveen) questionnaire [20], the Neurogenic Bowel Dysfunction Score (NBD) [21], the International Index of Erectile Function (IIEF) [22], and the Female Sexual Function Index (FSFI) [23]. The ASP has been validated to assess different components of the autonomic nervous system [19]. It includes 169 questions and measures 11 domains of autonomic function. The Orthostatic Intolerance domain of the ASP was used in this study which consists of nine items [19]. The Qualiveen assesses the impact of bladder function on the quality of life for individuals with SCI [20]. It is a 30-item questionnaire that assesses four aspects of patients' lives: Bother with Limitations (9 items), Frequency of Limitations (8 items), Fears (8 items), and Feelings (5 items) [24]. In this study, the Overall Quality of Life score was used, which is the mean of the 30 items (Qualiveen Composite score) [24]. The NBD is a 10-item measure of bowel function and there is evidence to support its validity in individuals with SCI [21]. The NBD measure includes a Total score (NBD Total score) which was used in this study. IIEF and FSFI sexual function measures were recommended by an expert panel at the National Institute on Disability and Rehabilitation Research SCI Measures Meeting [22, 23, 25]. IIEF is a multidimensional scale for the assessment of erectile dysfunction. It consists of 15 items and five domains which are Erectile Function (6 items), Orgasmic Function (2 items), Sexual Desire (2 items), Intercourse Satisfaction (3 items), and Overall Satisfaction (2 items) [22]. IIEF Erectile Function domain score, Orgasmic Function domain score and ejaculation item were used in this study. FSFI is a self-report instrument for assessing female sexual functions. It comprises 19 items and six domains which include Desire (2 items), Arousal (4 items), Lubrication (4 items), Orgasm (3 items), Satisfaction (3 items), and Pain (3 items) [23]. FSFI Arousal and Orgasm domain scores were used in this study.

Mapping and a priori hypotheses generation. A priori hypotheses were generated on how the ISAFSCI items for the General Autonomic Function component and Lower Urinary Tract, Bowel and Sexual Function component were expected to correlate with items, domains and/or composite scores from measures considered to assess similar constructs (convergent hypotheses) as well as with clinical variables such as injury level and severity (clinical hypotheses).

General autonomic function

There was one convergent and five clinical a priori hypotheses for the General Autonomic Function component. The convergent hypothesis was that the orthostatic hypotension item under the autonomic control of blood pressure section would correlate with question 1 of Orthostatic Intolerance domain from the ASP measure. Five clinical hypotheses were generated for each of the five sections under the General Autonomic Function component based on neurological level and/or injury severity (T5 and AIS A/B vs C/D, T5 and AIS A/B vs C/D, L2, T1 and AIS A/B vs C/D and C3-C5 and AIS A/B vs C/D respectively).

Lower urinary tract, bowel and sexual function

There were seven convergent and five clinical a priori hypotheses generated for this component of ISAFSCI. For the convergent hypotheses, the ISAFSCI composite bladder score [i.e., on awareness of the need to empty the bladder and ability to prevent leakage (continence) items] was hypothesized to correlate negatively with the Qualiveen Composite score. Similarly, the ISAFSCI composite bowel score [i.e., on the sensation of need for bowel movement and ability to prevent stool leakage (continence) items] was hypothesized to correlate negatively with NBD Total score. For sexual function in males, it was hypothesized that the ISAFSCI psychogenic genital arousal item correlates positively with IIEF Erectile Function domain score, the ISAFSCI orgasm item correlates positively with IIEF Orgasmic Function domain score, and that the ISAFSCI ejaculation item correlates positively with IIEF ejaculation item. Similarly, for sexual function in

females, we hypothesized that the ISAFSCI psychogenic genital arousal item would correlate positively with FSFI Arousal domain score and the ISAFSCI orgasm item would correlate positively with FSFI Orgasm domain score. For the clinical hypotheses, the ISAFSCI composite bladder score, composite bowel score, ISAFSCI psychogenic genital arousal item for males and females were hypothesized to correlate positively with ISNCSCI composite pinprick score. Lastly, the ISAFSCI sensation of menses item was hypothesized to correlate negatively with females being over the age of 50.

Statistical analysis

ISAFSCI responses for the General Autonomic Function component were coded as Present = 1, Absent = 2, Unknown = 3 and ISAFSCI responses of 'Unknown' and 'NT' were treated as missing. The composite scores for some hypotheses were defined as the average score of specified items of the same sections for ISAFSCI and the same domains for the standard measures. For IIEF/FSFI, a domain score was calculated as the total score of specified items for the same domain as in Rosen et al. [22, 23].

A priori hypotheses were tested using either the Chi-square test (Fisher's exact test if the expected cell counts were less than five) or a correlation test (Spearman's rho). Specifically, since the General Autonomic Function component uses a nominal scale, the Chi-square test was used. Whereas because the Lower Urinary Tract, Bowel and Sexual Function component uses an ordinal scale, Spearman's rho was used and both the strength and significance of the correlations were assessed. The strength of the correlations was assessed as: ≥0.70 = strong, 0.50–0.69 = good, 0.31–0.49 = fair, and ≤0.30 = weak [26]. Associations with p-values < 0.05 were considered statistically significant. All analyses were performed using SAS software, Version 9.4 of the SAS System for Windows. Copyright © 2013. SAS Institute Inc., Cary, NC, USA.

RESULTS

Participant characteristics

Participants ($n = 49$) had an average age of 45 ± 12 years. Forty-two (85.7%) were male, 23 (46.9%) had a motor and sensory complete SCI, 37 (77.6%) had an at or above T6 level of injury, and 31 (63.3%) were living with tetraplegia. The median time since injury was six years (Table 1).

Table 1. Participant Characteristics.

Variable	Analysis cohort $n = 49$
Age at injury (years); mean (SD)	45 (12)
Male; *n* (%)	42 (85.7)
Injury severity (AIS); *n* (%)	
A	23 (46.9)
B	8 (16.3)
C	4 (8.2)
D	13 (26.5)
Neurological level; *n* (%)	
High cervical (C1–C4)	18 (37.5)
Low cervical (C5–T1)	13 (27.1)
Thoracolumbar (T2–S5)	17 (35.4)
SCI at or above T6; *n* (%)	37 (77.6)
Extent of SCI; *n* (%)	
Paraplegia	15 (30.6)
Tetraplegia	31 (63.3)
Cauda equina syndrome	2 (4.1)
Caucasian; *n* (%)	38 (79.6)
Some college or above; *n* (%)	40 (81.6)
Time since injury (years); median (IQR)	6.0 (0.0)

AIS ASIA Impairment Scale (A, B, C, D), *SCI* spinal cord injury, *SD* standard deviation, *IQR* inter-quartile range.

General autonomic function

For the convergent hypothesis test, the item on orthostatic hypotension under autonomic control of blood pressure section was significantly correlated with the ASP measure Orthostatic Intolerance domain question 1 ($p = 0.01$). In terms of the clinical hypotheses, the bradycardia item of autonomic control of the heart section was not associated with AIS and injury level T5 ($p = 0.35$). Autonomic control of blood pressure items was significantly associated with AIS and injury level T5 ($p < 0.0001$). Normal control of sweating items from the autonomic control of the sweating section was not associated with injury level L2 ($p = 1.0$). The hypothermia item under the temperature regulations section correlated significantly with AIS A/B and injury level above T1 ($p = 0.04$). The item on impaired voluntary breathing requiring partial ventilatory support under autonomic and somatic control of the broncho-pulmonary system section was not associated with AIS and neurological level C3-C5 ($p = 0.65$) (Table 2).

Lower urinary tract, bowel and sexual function

For the convergent hypotheses related to the bladder, the correlation between ISAFSCI composite bladder score and Qualiveen Composite score was fair and significant (rho = −0.33, $p = 0.02$). Similarly, the ISAFSCI composite bowel score had a fair and significant (rho = −0.37, $p = 0.01$) correlation with NBD Total score. For sexual function, the ISAFSCI psychogenic genital arousal item for males had a good correlation with IIEF Erectile Function domain score and the correlation was highly significant (rho = 0.59, $p < 0.0001$). The correlation between ISAFSCI male orgasm item and IIEF Orgasmic Function domain score was fair and significant (rho = 0.45, $p = 0.0003$). The correlation between the ISAFSCI and IIEF ejaculation items was good and highly significant (rho = 0.60, $p < 0.0001$). Tests for the two convergent hypotheses on ISAFSCI female sexual items did not have a large enough sample size to detect statistical significance (Table 3).

For the clinical hypotheses, the ISAFSCI composite bladder score correlated fairly well with the ISNCSCI composite pinprick score (rho = 0.45, $p = 0.003$). Similarly, the correlation between ISAFSCI composite bowel score and ISNCSCI composite pinprick score was good and significant (rho = 0.55, $p = 0.0002$). ISAFSCI psychogenic genital arousal item for males had a good and highly significant correlation with ISNCSCI composite pinprick score (rho = 0.68, $p < 0.0001$). Tests for the two clinical hypotheses on ISAFSCI female sexual items did not have a large enough sample size to detect statistical significance (Table 3).

DISCUSSION

This is the first study to evaluate the validity of the ISAFSCI in individuals with traumatic SCI. The construct validity of ISAFSCIv1 for the General Autonomic Function component was considered to be weak based on the hypothesized correlation with other measures and our clinical hypotheses. For the six General Autonomic Function component hypotheses, two hypotheses (one clinical, one convergent) related to autonomic control of blood pressure and one clinical hypothesis for temperature regulation were statistically significant, indicating that on the whole, the General Autonomic Function component of the ISAFSCI does not have the validity that the clinical community would need in a bedside assessment of autonomic function. For the Lower Urinary Tract, Bowel and Sexual Function component, the construct validity was much stronger, and therefore more useful in the day-to-day clinical assessment of autonomic function. For this component, all of the hypotheses (five convergent, three clinical) were statistically significant except for the hypotheses on

Table 2. General Autonomic Function Component Hypotheses Generation Details and Test Results.

General Autonomic Function	Correlated with	Hypothesis type	Hypotheses	Standardized question asked during ISAFSCI assessment	Sample size	Test Results *P*-value
Autonomic control of the heart	AIS A/B vs C/D and injury level T5	Clinical	H1: Bradycardia item correlates with AIS (A/B vs C/D) and injury level at or above T5	At rest, do you have a heart rate lower than 60 beats per minute? At rest, do you have a heart rate greater than 100 beats per minute? Have you ever experienced, or been told that you have an arrhythmia, or irregular heart rate?	48	0.35
Autonomic control of blood pressure	AIS A/B vs C/D and injury level T5 ASP q1: In the past year, have you ever felt faint, dizzy, or 'goofy' or had difficulty thinking soon after standing up from a sitting or lying down position?	Clinical Convergent	H2: Control of blood pressure item correlates with AIS (A/B vs C/D) and injury level below/above T5 (i.e., normal response correlates with below T5 and the rest of the abnormal conditions correlate with above T5) H3: Orthostatic hypotension item correlates with ASP measure Orthostatic Intolerance domain q1	At rest, do you have a systolic blood pressure lower than 90 mmHg? In the last 6 months, have you experienced, or been told that you have a condition called 'Orthostatic Hypotension'? Have you ever experienced, or been told that you have a condition called 'Autonomic Dysreflexia'?	48 48	**<0.0001** **0.01**
Autonomic control of sweating	Injury level L2	Clinical	H4: Normal control of sweating item correlates with injury level below L2	Do you sweat the same amount and as often now, compared to before your injury?	48	1.0
Temperature regulations	AIS A/B vs C/D and injury level T1	Clinical	H5: Hypothermia item correlates with AIS A/B and injury level above T1	Has your ability to control your own body temperature changed since your injury? Do you have a difficult time remaining cool in a hot environment? Do you have a difficult time remaining warm in a cool environment?	48	**0.04**
Autonomic and Somatic control of broncho-pulmonary system	AIS A/B vs C/D and injury level C3–C5	Clinical	H6: Impaired voluntary breathing requiring partial ventilatory support item correlates with AIS A/B and injury level C3–C5	Has your ability to control your breathing/coughing/respiration changed since your injury? Are you unable to voluntarily breathe without ventilator support? Do you have impaired voluntary breathing requiring ventilator support part of the time? Do you have impaired voluntary respiration, but do not require ventilator support at any time?	48	0.65

Bold values indicate statistical significance $p < 0.05$.
q1 question 1, *ASP* Autonomic Symptom Profile, *AIS* ASIA Impairment Scale (A, B, C, D), *H* hypothesis.

Table 3. Lower Urinary Tract, Bowel and Sexual Function Component Hypotheses Generation Details and Test Results.

Lower Urinary Tract, Bowel and Sexual Function		Correlated with	Hypothesis type	Hypotheses	Standardized question asked during ISAFSCI assessment	Sample size	Test Results	
							Spearman correlation	*P*-value
Lower urinary tract	Awareness of the need to empty the bladder	Qualiveen Composite score ISNCSCI composite pinprick score	Convergent Clinical	H7: ISAFSCI composite bladder score correlates negatively with Qualiveen Composite score H8: ISAFSCI composite bladder score correlates positively with ISNCSCI composite pinprick score of 2	Do you have an awareness of the need to empty your bladder? Do you have the ability to prevent leakage (continence)?	48 42	−0.33 0.45	**0.02** **0.003**
	Ability to prevent leakage (continence)							
Bowel	Sensation of need for bowel movement	NBD Total score ISNCSCI composite pinprick score	Convergent Clinical	H9: ISAFSCI composite bowel score correlates negatively with NBD Total score H10: ISAFSCI composite bowel score correlates positively with ISNCSCI composite pinprick score of 2	Do you have the sensation of need for a bowel movement? Do you have the ability to prevent stool leakage(continence)?	47 42	−0.37 0.55	**0.01** **0.0002**
	Ability to prevent stool leakage (continence)							
Sexual function	Genital arousal (erection or lubrication)	IIEF q1: how often were you able to get an erection during sexual activity? IIEF q2: When you had erections with sexual stimulation, how often were your erections hard enough for penetration? IIEF q3: When you attempted intercourse, how often were you able to penetrate your partner? IIEF q4: During sexual intercourse, how often were you able to maintain your erection after you penetrated? IIEF q5: During sexual intercourse, how difficult was it to maintain your erection to completion of intercourse? FSFI q3: Over the past 4 weeks, how often did you feel sexually aroused during sexual activity or intercourse? FSFI q4: Over the past 4 weeks, how would you rate your level of sexual arousal during sexual activity or	Convergent Clinical Convergent Clinical	Males: H11: ISAFSCI psychogenic genital arousal item correlates positively with IIEF Erectile Function domain score H12: ISAFSCI psychogenic genital arousal item correlates positively with ISNCSCI composite pinprick score of 2 Females: H15: ISAFSCI psychogenic genital arousal item correlates positively with FSFI Arousal domain score 16: ISAFSCI psychogenic genital arousal item correlates positively with ISNCSCI composite pinprick score of 2	Are you able to experience genital arousal (erection/ vaginal lubrication/wetness) a. By thinking sexual thoughts? b. By reflex or touch?	42 38 7 5	0.59 0.68 - -	**<0.0001** **<0.0001** --

Table 3. continued

Lower Urinary Tract, Bowel and Sexual Function		Correlated with	Hypothesis type	Hypotheses	Standardized question asked during ISAFSCI assessment	Sample size	Test Results	
							Spearman correlation	*P*-value
		intercourse? FSFI q5: Over the past 4 weeks, how confident were you about becoming sexual aroused during sexual activity or intercourse? FSFI q6: Over the past 4 weeks, how often have you been satisfied with your arousal during sexual activity or intercourse?						
	Orgasm	IIEF q7: When you attempted sexual intercourse, how often was it satisfactory for you? IIEF q8: How much have you enjoyed sexual intercourse? FSFI q11: Over the past 4 weeks, when you had sexual stimulation or intercourse, how often did you reach orgasm? FSFI q12: Over the past 4 weeks, when you had sexual stimulation or intercourse, how difficult was it for you to reach orgasm? FSFI q13: Over the past 4 weeks, how satisfied were you with your ability to reach orgasm during sexual activity or intercourse?	Convergent Convergent	Males: H13: ISAFSCI orgasm item correlates positively with IIEF Orgasmic Function domain score Females: H17: ISAFSCI orgasm item correlates positively with FSFI Orgasm domain score	Are you able to experience orgasm?	41 7	0.45 -	**0.0003**
	Ejaculation (male only)	IIEF q9: When you had sexual stimulation or intercourse, how often did you ejaculate?	Convergent	H14: ISAFSCI ejaculation item correlates positively with IIEF ejaculation item	Are you able to ejaculate? (Male only)	42	0.60	**<0.0001**
	Sensation of Menses (female only)	Females being over the age of 50	Clinical	H18: ISAFSCI sensation of menses item correlates negatively with females being over the age of 50	Do you have the sensation of menses? (Female only)	6	-	-

Bold values indicate statistical significance $p < 0.05$.

q1 question 1, *AIS* ASIA Impairment Scale (A, B, C, D), Qualiveen, Quality of Life of Spinal Cord Injury Patients; *NBD* Neurogenic Bowel Dysfunction Score, *IIEF* International Index of Erectile Function, *FSFI* Female Sexual Function Index, *ISNCSCI* International Standards for Neurological Classification of Spinal Cord Injury, *H* hypothesis, "-" not reported due to small sample size.

female sexual items (two convergent, two clinical), likely due to the sample size of female participants.

A priori clinical hypotheses indicated that the General Autonomic Function component of ISAFSCIv1 has weak construct validity. Bradycardia did not correlate with the hypothesized neurological level of T5 and AIS groups while autonomic control of blood pressure was significantly associated with the hypothesized neurological level of T5 and AIS groups. Inconsistencies between motor completeness and autonomic completeness for cardiovascular function in individuals with SCI have previously been reported in the literature [27]. In a systematic review, West et al. concluded that for chronic SCI, studies suggest that autonomic completeness of SCI is more related to cardiovascular function than neurological completeness of injury [28]. When the effect of neurological level, along with motor, sensory, and autonomic completeness of injury was assessed on cardiovascular control in Paralympic athletes with SCI, only neurological level and autonomic completeness were strong predictors [29]. Ravensbergen et al. reported that the odds of bradycardia and hypotension were significantly higher in those with cervical and high thoracic lesions compared to those with lesions below T5 while the completeness of injury as determined by AIS classification did not influence the odds [30]. Hypotheses on the associations of bradycardia and autonomic control of blood pressure with injury level and severity individually in this study were similar to the findings in these studies (statistically significant association with level but not significant association with AIS).

The Lower Urinary Tract, Bowel and Sexual Function components demonstrated construct validity, especially for the male sexual function items. The ISAFSCI composite bladder score was significantly negatively correlated with the Qualiveen Composite score. Welk et al. reported that the incontinence domain of Neurogenic Bladder Symptom Score, a scale developed for individuals with neurogenic bladder dysfunction including SCI, had a moderate positive correlation with the Qualiveen Composite score (Pearson rho = 0.46, $p < 0.001$) [31]. The different health conditions and measures validated may explain the variation observed.

The differences seen in the two major components of ISAFSCI assessment may be influenced by how items were designed and scored. In the ISAFSCIv1, items in the General Autonomic Function component use a nominal scale (with two nominal response options) while the Lower Urinary Tract, Bowel and Sexual Function component use an ordinal scale (with three numeric response options). With the latter option, it may be easier for the assessor to pick a more objective and accurate response.

In the recently published ISAFSCIv2, numerous improvements over the ISAFSCIv1 have been made. In addition to language changes and clarifications, definitions of abnormal conditions are now added in the new assessment form directly. With respect to scoring, items in the General Autonomic Function component are now scored using an ordinal scale (normal = 2, altered = 1 and absent = 0 when applicable) [15]. In our study, we generated standard questions to facilitate the ISAFSCIv1 assessment data collection. Similar standardized questions now have been added for the assessment recommendations for the Lower Urinary Tract, Bowel and Sexual Function component in ISAFSCIv2. The work conducted in this study provides a foundation for future studies that may assess the construct validity of the ISAFSCIv2.

This study has limitations. First, our study was a pilot study with only 7 females which led to a sample size that was too small to test any hypothesis for this group of participants. Future studies of ISAFSCIv2 should implement a recruitment strategy for females to increase sample size and assure sex and gender equity. Second, some clinical hypotheses may need to be re-considered or revised based on our results in the future. For example, hypothesis tests of bradycardia and autonomic control of blood pressure with hypothesized injury level and severity individually produced results that are consistent with the literature [30]. Future evaluations of the ISAFSCIv2 should consider neurology level and severity independently. Third, in this study, maintenance of pinprick at levels T10, T11, T12, and L1 was used as a surrogate measure of autonomic neurological function for some clinical hypotheses (e.g. bowel/bladder/sexual functioning) [32]. More recent literature has considered somatic and autonomically mediated reflexes such as the anal wink, bulbocavernosus, adductor, cremaster, abdominal, dartos and vasomotor reflexes to predict intact autonomic function at these levels (e.g. sexual function) [33]. Future research should consider including these reflexes when predicting responses on the ISAFSCIv2. Fourth, the availability of standard measures limited our ability to evaluate the General Autonomic Function component. While there were seven convergent hypotheses generated as *priori* for the Lower Urinary Tract, Bowel and Sexual Function component of ISAFSCI, there was only one similar convergent hypothesis in the General Autonomic Function component. Future studies evaluating the construct validity of ISAFSCIv2 could work on identifying more standard measures for the General Autonomic Function component. Lastly, there is very little research on autonomic function measures and the ISAFSCI, so it was difficult to compare our results.

In conclusion, the construct validity of ISAFSCI (2012 1st Edition) for the General Autonomic Function component was considered to be weak while it was much stronger for the Lower Urinary Tract, Bowel and Sexual Function component based on a priori hypotheses. For the clinical hypotheses, motor completeness did not correlate well with autonomic completeness. These results may inform future psychometric studies of the ISAFSCIv2 and further revisions to the ISAFSCI.

DATA AVAILABILITY

The datasets analysed during the current study are available from the corresponding author on reasonable request.

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AUTHOR CONTRIBUTIONS

DK was responsible for statistical analysis, interpreting the results and writing the manuscript. RD and MC contributed to the study design, generated the hypotheses, collected data, interpreted the results and edited the manuscript. KS and JJ supervised data collection, interpreted the results and edited the manuscript. SE contributed to the study design, generated the hypotheses, interpreted the results and edited the manuscript. VN provided input on the analysis plan, hypotheses generation, interpreting the results and edited the manuscript. NF provided feedback on the analysis and edited the manuscript. AK supervised the project and study design, provided feedback on the generation of hypotheses and edited the manuscript.

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COMPETING INTERESTS

DK, NF and VN are employees of the Praxis Spinal Cord Institute. The other authors declare that there are no competing financial interests or conflict of interests in relation to the work described.

ETHICAL APPROVAL AND CONSENT TO PARTICIPATE

Research Ethics Board (REB) approval from the hospital and university was obtained for this work. We further certify that all applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during the course of this research and that informed consent was obtained from all participants.

ADDITIONAL INFORMATION

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